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Enhanced DV-Hop Localization Algorithm for Wireless Sensor Networks

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ABSTRACT

The Wireless Sensor Networks Localization is an important area due to its wide spread application in the all fields. Hence in this work, an improved Distance- Vector technics is used to reduce the localization error of target nodes in the wireless sensor networks. The proposed technique is an modification over classical D-V hop algorithm.

The importance of localization of unknown sensor nodes in WSN is an emerging area due to the wide use of applications. Hence in this paper, an advanced Distance-Vector algorithm is proposed to improve the localization or positional accuracy of unknown sensor nodes. The proposed algorithm is an enhancement over traditional over classical Distance Vector algorithm. The main goal of this algorithm is minimize the error generated during the calculation of average hop size value with the help of weighted correction on average hop size. And further improvement in positional accuracy of sensor node is maintained by using WLS algorithm, by considering the distance between anchor nodes and unknown sensor nodes. Simulation results are generated by using MATLAB and the localization accuracy or error compared with classical DV-hop, improved method by changing the parameters like radius of communication of nodes, density of sensor nodes and percentage of anchor counts.

KEYWORDS: *DV-Hop, hop-size value, localization, weighted correction WLS, wireless sensor networks*

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1. INTRODUCTION

Wireless Sensor Network contains a large number of sensor nodes and this sensor nodes are inter connected with advanced wireless technology. And each of this sensor node is equipped with sensing capability with the help of sensors, processing capability with the help of processors and transmitting capability with the help of transceivers [1]. The application of wireless sensor network can be used in different y areas like Transportation and Logistics, industrial application, precision agriculture and animal tracking, urban terrain tracking, entertainment, smart grid and energy control system, health care systems [2] and so forth.

It is very clear that from many of the wireless sensor network applications, the positions of the event or outcome along with sensed data and also to find out the position of each sensor node is not easy because of the wireless sensor network constraints like size of the sensor nodes, power consumption, cost of the system and also computational overhead. [3] The manual configuration is very easy to localize each sensor node but it is impossible in the case of large sensor nodes and also the use of global positioning system (GPS) module is practicably not feasible because of line-of-sight problem, energy consumption and cost of the system and size of sensor nodes [3]. To manage this problem researchers are developed many wireless sensor localization algorithms. And the developed technics are broadly categorized into two groups called range-free and range-based localization algorithm [4].

Basically range-free methods are very simple and less cost because in this method technically no extra

hardware is used to calculate the distance among anchor sensor nodes and unknown sensor nodes. In this method the average distance calculation is done with the help of hop count and it is implemented by using the already available communication system and the same is transmitted along with information data packets. Some of the commonly used range free methods are DV-hop, Centroid, Approximate Point-in triangle (APIT). In the range based method, it uses technically additional hardware to estimate the distance between anchor sensor nodes and unknown sensor nodes, hence it is comparatively costlier than range free method. Some of the most popular range based methods are AoA(Angle of Arrival), RSSI, TDOA,TOA [5-6].

To improve the localization accuracy, researchers are tried to reduce the error generated during the average hop size calculation in classical dv hop algorithm, because this average hop size value is used many times to find out the geographical position of unknown nodes hence the error accumulation is increased in each steps. This average hop value is estimated by already configured sensor nodes called anchor sensor nodes or beacon sensor nodes with the help of manual configuration or GPS. In the first step beacon sensor nodes sends a packet containing it's id, geographical position and hop count to all nodes. By using this packet, each unknown sensor nodes keep a table containing beacon nodes geographical position and hop count. By using this data and average hop size the unknown sensor nodes itself can calculate it's geographical position by using triangulation, trilateration or maximum likelihood methods [7,9].

To improve the localization/position accuracy an enhanced dv-hop method is used upon classical dv-hop algorithm. In which weighted least square method is used finally to find (x,y) values of unknown sensor nodes [10-11]. In between minimum mean square method is implemented on average-hop size calculated by traditional algorithm and also 2-D hyperbolic equations are also used before squaring the variables which further helps to reduce error in average hop-value. The proposed method is simulated with respect to sensor area parameters like communication radius, beacon percentage and total number of sensor-nodes. The graphical output compared with traditional DV-hop and improved dv-hop to justify the results.

The rest of the parts are arranged for review related works in Part 2 and Part 3 depicts the traditional dv-hop and enhancements to implement proposed technique and continuing parts are used for simulation graphs and finally concluded future work.

2. RELATED WORKS

This section is mainly focusing on important DV-hop range-free algorithms and improvements on it.

Javed Iqbal Bangash et al[15], in this paper the author explained process in localization, challenges and issues related with Wireless Sensor Networks. The different processes in localization are Angle/Distance Estimation, Location measurements and different algorithm for location finding. The distance or angle measurements can be done with the following techniques RSSI, ToA, RToA, TDoA, AoA and light-house method. And the calculation of location can be done with Trilateration, Triangulation or by using maximum-likelihood multi-lateration. Localization algorithm is grouped into centralized and distributed methods. In centralized method, it run on a central machine and doing all the complicated mathematics on this machine but in the distributed method, all the operations to find out x and y coordinates are distributed among all sensor nodes. The author also explained the important challenges and issues in connection with the networks. The major problems are consumption of energy, localization methods to solve the coordinates in 3D topology, localization methods for mobile-WSN, security issues and minimization of anchor nodes.

N.M. Ngabas et al[16] In this paper the author used a selective forwarding in the traditional DV-Hop methods by considering both accuracy and energy before forwarding the packets by using MDP(Markov Decision Process).In the traditional DV-hop method, he packets are flooded which causes the energy loss for sensor nodes because most of the energy depletion is due to communication states like packet transmission, Reception also idle states, so for energy efficient methods it required to reduce the flooding rate or reduce the duplicate packet forwarding. In this method to solve this problem some additional information is added into the packet, hence this method is also called packet content driven methods. The basic parameters considered before forwarding the packets are energy level and quality of data. At the starting point the sensor checks the energy capacity and if it is low it goes to sleep mode else it tests the level of localization accuracy, that is the sensor only forwards the packet based on accuracy and energy at that particular instant, for this purpose each sensor is defined into following levels called state, nature of action, probability of transition and reward received.

Xiu-wu Yu et al[17], in this paper the error generated in classical DV-Hop, while calculating the distance value between beacon node and target node is reduced by using error-correction method and multi-hop techniques. In this method the average hop-size error is reduced by using error factor which is connected with hop-count and distance among anchor nodes. And the distance between target-node and beacon node is estimated with respect to the relative position of anchor nodes. That is if anchor node is nearest, then it simply multiplies the average size by hop-count. And if the beacon node is greater than the minimum hop-count, the calculation is done by comparing angles. And the hop is in-between above two cases, some scaling factor is used to find the distance. The x and y values of unknown node is measured by taking ratio between square of the distance of target node and beacon node. And finally the result is evaluated by using average error in localization and relative accuracy of positioning.

R. Khadim et al[18], In this paper, the author explains different range free localization methods, which depends only on the connectivity between the nodes, that is no extra hardware is required like in range based methods. In this method it supports comparatively lower consumption of power, ability against noise and scalability of the network. The author explained the following range-free methods, centroid method, distance vector hop and amorphous methods. In centroid method, the target node x and y values are calculated by using centroid methods by using the positions of available beacon nodes. In distance-vector hop method, the co-ordinates of target node are measured by using the average hop value calculated between beacon nodes. The amorphous method is same as DV-Hop, the difference is while calculating hop distances.

The proposed work is improved by using weighted correction and weighted least square method and also localization accuracy is analyzed in terms of radius of sensor node, beacon node percentage and number of sensor nodes.

3. ADVANCED DV-HOP LOCALIZATION METHOD

Proposed method implemented by using weighted correction and updated the average hop size to reduce the error and also used weighted least square method.

3.1. Traditional dv-hop method

Initially the hop size value is estimated by using classical dv-hop method. In the first step, the anchor nodes broadcasts a packet consists of geographical position of anchor nodes and hop count [12]. By using this data, anchor node estimates hop-size value for each anchor sensor node as given below.

$$hopsize_j = \frac{\sum\sqrt{(x_j - x_k)^2 + (y_j - y_k)^2}}{\sum h_{jk}}, (j \neq k) \ (1)$$

Where (x_j, y_j) is the co-ordinates of the j^{th} anchor sensor nodes and (x_k, y_k) is the k^{th} anchor sensor node co-ordinates, (h_{jk}) is the hop count between anchor node j and anchor node k.

3.2. Error reduction by weighted correction

Here a weighted value is added to average hop size for reducing the error between actual geographical location of unknown sensor node and estimated location. Due to the random distribution of sensor nodes, the unknown sensor node receives several hop size from the surrounding beacon nodes and also the closer beacon node have greater influence during average hop size calculation, to solve this average hop size is calculated then a weighted correction is added to the average hop size as given below

Average hop size is

$$average\_hop = \left\{\frac{\sum_{i=1}^{m} hopsize_i}{m}\right\} \ (2)$$

Where $hopsize_i$ is calculated as per equation (1), m is the number of anchor nodes

The correction value calculated for reducing the error is

$$correction = \sum\left[\left|d - average_{hop} \times hop(i,j)\right|/hop(i,j)\right] \ (3)$$

In equation

d= $\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$ denotes actual distance between two nodes i and j and hop(i,j) indicates hop count between node i and node j.

Now the corrected hop size is

HopSize = average_hop + correction

And this HopSize is used for further calculation.

3.3. Localization of unknown nodes

Calculation of (x, y) co-ordinates

Let (x, y) be the unknown sensor node co-ordinates and (x_1, y_1) to (x_P, y_P) indicates the M anchor sensor node co-ordinates.

$$\sqrt{(x-x_1)^2+(y-y_1)^2} = d_1$$

$$\sqrt{(x-x_2)^2+(y-y_2)^2} = d_2$$

$$\vdots \quad (5)$$

$$\sqrt{(x-x_P)^2+(y-y_P)^2} = d_P$$

For solving the eqn. (5), it is squared then subtract P th equation from all equations and solve it by matrix method. But from eqn. (5) it is clear that by squaring the error due to Hopsize increases abruptly, hence to minimize the error in Hopsize while solving (x,y) co-ordinates, it is better to subtract first then square.

Hence by subtracting Pth equation we will get eqn. (6)

$$\sqrt{(x-x_1)^2+(y-y_1)^2} - \sqrt{(x-x_P)^2+(y-y_P)^2} = d_1\text{-}d_P$$

$$\sqrt{(x-x_2)^2+(y-y_2)^2} - \sqrt{(x-x_P)^2+(y-y_P)^2} = d_1\text{-}d_P$$

$$\vdots \quad (6)$$

$$\sqrt{(x-x_{p-1})^2+(y-y_{p-1})^2} - \sqrt{(x-x_P)^2+(y-y_P)^2} = d_1\text{-}d_P$$

Squaring and re-arranging eqn. (6) we get eqn. (8) as

$$-2(x_2+x_p)x - 2(y_2+y_p)y + 2k = d_1^2 + d_p^2 - (V_1+V_P)$$

$$-2(x_2+x_p)x - 2(y_2+y_p)y + 2k = d_2^2 + d_p^2 - (V_2+V_P)$$

$$\vdots \quad (7)$$

$$-2(x_{p-1}+x_p)x - 2(y_{p-1}+y_p)y + 2k = d_{p-1}^2 + d_p^2 - (V_{p-1}+V_P)$$

Where k=(x^2+y^2) and $V_i = x_p^2 + y_p^2$, i=1,2,3,.. .. .p

Writing the above equations in the matrix form AX=B.

Then

$$A=\begin{bmatrix} -2(x_1+x_P) & -2(y_1+y_P) & 1 \\ -2(x_2+x_P) & -2(y_2+y_P) & 1 \\ & \vdots & \\ -2(x_{p-1}+x_P) & -2(y_{p-1}+y_P) & 1 \end{bmatrix} \quad (8)$$

$$B=\begin{bmatrix} d_1^2+d_p^2-(V_1+V_P) \\ d_2^2+d_p^2-(V_2+V_P) \\ . \\ . \\ d_{p-1}^2+d_p^2-\left(V_{p-1}+V_P\right) \end{bmatrix} \quad (9)$$

$$Z=\begin{bmatrix} x \\ y \\ k \end{bmatrix} \quad (10)$$

To improve the accuracy of position of unknown sensor nodes the above matrices are solved by using WLS technique, that is

$$Z=(A'W'WA)^{-1}A'W'WB \quad (11)$$

Where W is used to represent weighted matrix for the unknown nodes, which contains least number of hops from beacon sensor nodes.

$$W=\begin{bmatrix} w_{p,1}\ 0\ldots 0 \\ 0\ w_{p,2}\ldots 0 \\ . \\ . \\ 0\ 0\ldots w_{p,n-1} \end{bmatrix} \quad (12)$$

Where $w_{p,j}={}^{1}/_{h_{p,j}}$, the weight factor for unknown sensor is the reciprocal of the minimum hop count to the j th anchor node, hence it reduces the chances of error when the anchor node is far away from unknown sensor node.

On solving equation (15), we will get three values (x,y,k), due to the error occurred in d_p, the equation k=$(x_p^2+y_p^2)$ will not satisfy, hence it is required to update the (x, y) co-ordinates as given below

$$t=\sqrt{\frac{k}{x_p^2+y_p^2}} \quad (13)$$

x1=x.t and y1=y.t

then $x^{est}=(x+x1)/2, y^{est}=(y+y1)/2$

4. RESULTS AND DISCUSSION

To simulate the Wireless Sensor Network data for the localization of unknown sensor nodes the MATLAB software is used.. And each plot compares the localization error of traditional DV-hop, DV-hop without updating and with updating and proposed algorithm. The variables used in the plot are radius of sensor node, anchor percentage and sensor node density in X axix and localization error in Y axis.

Table 1 Simulation area variables

Parameters	Value
Area of simulation	100 X 100 sq m
Communication range Radius	15 m to 35 m
Anchor values	5 numbers to 25 numbers
Total sensor nodes	200 numbers to 500 numbers

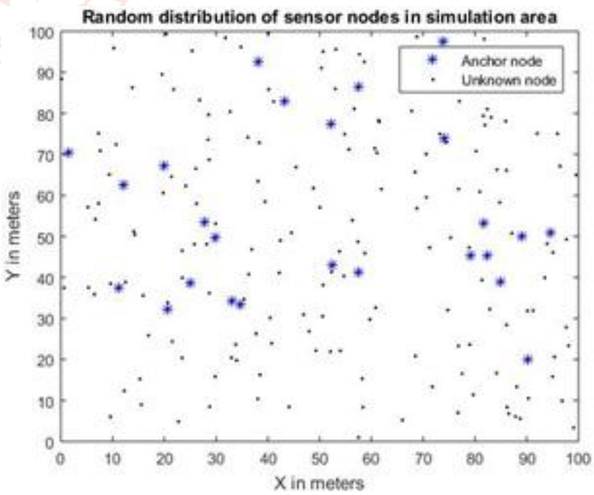

Fig. 1 Random distribution of sensor nodes in simulation area.

The localization error(average) is measured by the equation,

$$LE=\frac{\sum_{i=1}^{N-M}\sqrt{(x_i^e-x_i)^2+(y_i^e-y_i)^2}}{R*(N-M)} \quad (14)$$

Here M is used to indicate number of anchor nodes, N used for sensor nodes R is approximate radius for communication, (x_i, y_i) and (x_i^e, y_i^e) indicates actual and estimated (x, y) values.

4.1. Communication radius against error in localization (random topology)

The Fig. below plotted by using communication radius and localization error and total sensor nodes are fixed on the simulation area. Error plotted for 15m, 20m, 25m, 30m and 35m.And it is clear that the error reduces when radius increases because while increasing radius the hop-count decreases which further reduce the error produced due to avg. hop value.

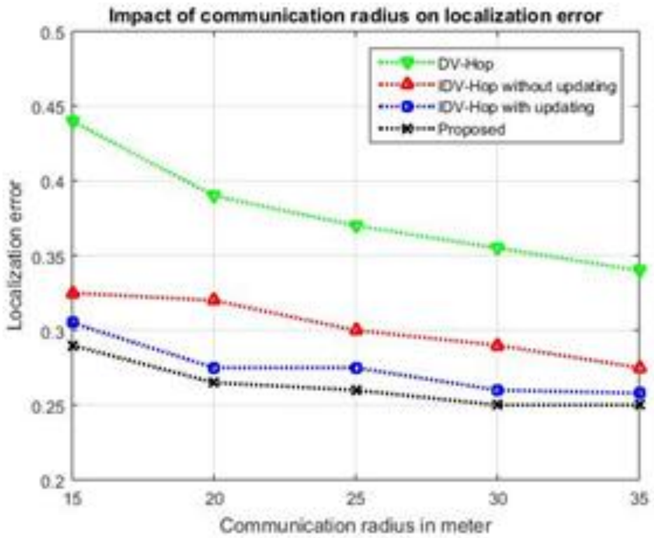

Fig. 1.1 radius range in communication against error in localization

4.2. Beacon nodes against Localization error (random topology)

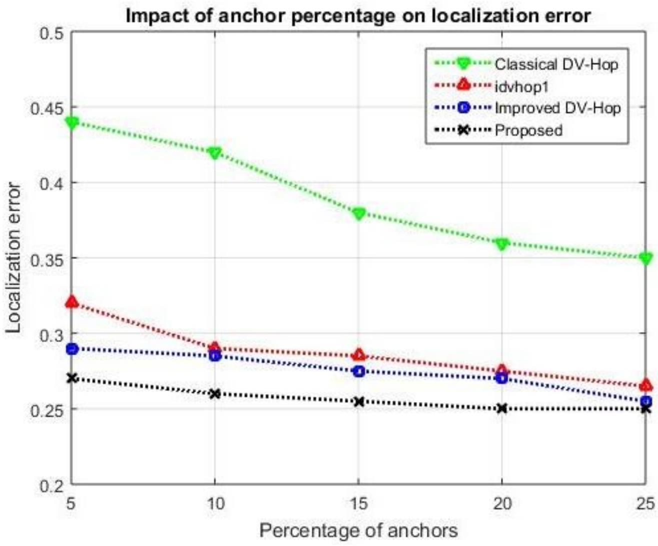

Fig. 1.2 Beacon Sensor node against localization error

In this plot, the range radius and total sensor nodes are fixed and anchor nodes are varied from 5 to 25 in numbers. In random network when the anchor number increases it reduce localization error initially at large level then going to saturation, because it indirectly reduces the error part in avg. hop value.

4.3. Sensor nodes against Localization error (random topology)

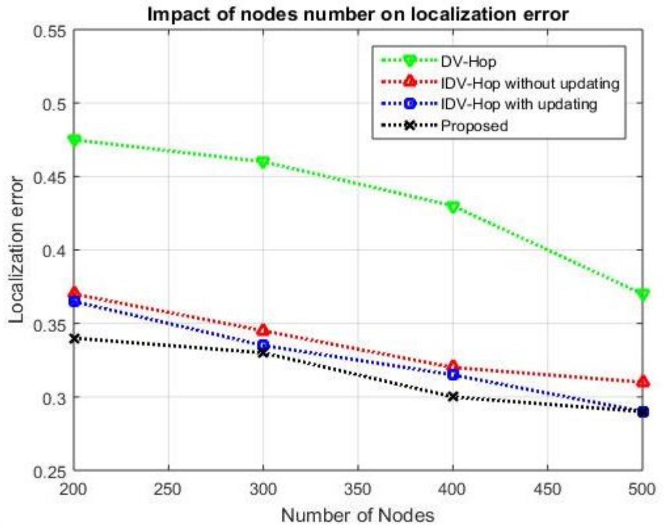

Fig. 1.3 The impact of sensor numbers against localization error

The above simulation is plotted for approximate circular radius fixed to 15 m, anchor is taken as 10 % of sensor nodes in each iteration and sensor nodes incremented from 200 to 500 with an incremental step of 50. Initially the localization error reduces with connectivity increasing, but further increasing will not result in localization accuracy.

5. CONCLUSIONS

In this method, the proposed localization algorithm is tried to improve the localization accuracy with weighted value in connection with anchor node distances. And this modification is done by calculating average hop size by using classical DV-hop algorithm. And further reduction in error is done by using WLS or weighted Least Square technique. It improves the accuracy by multiplying with weighted matrix. The weighted matrix diagonal elements are generated on the principle, which the error increases when the distance between anchor node and unknown sensor node is large which means number of hops is high. To solve this reciprocal of hops are taken to generate weighted matrix, which helps to reduce error due to average hop count value. Besides this, the initial error content of average hop-value is minimized by using minimum mean square equation. The proposed technique is simulated by incrementing parameters like density of sensor nodes, radius of communication range and anchor percentage in Random topology wireless sensor network. The simulation plots compared with traditional DV-hop algorithm.

One of the main drawbacks of this system is computational overhead and unlimited packet broadcasting during initial step of processing. Another future scope is 3D environment sensor nodes application.

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